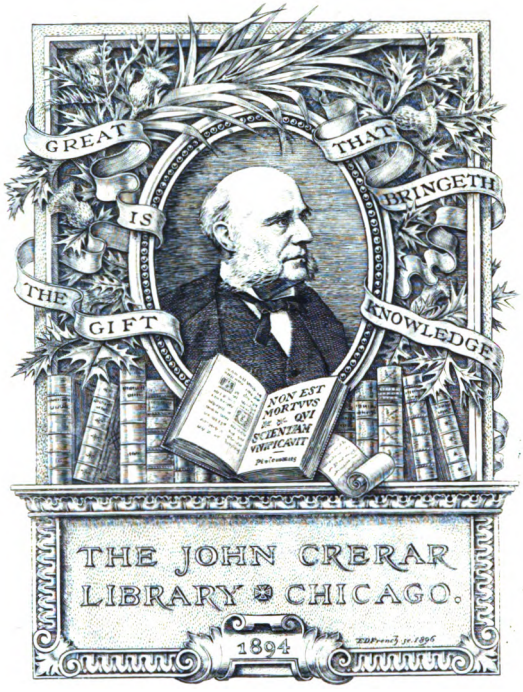
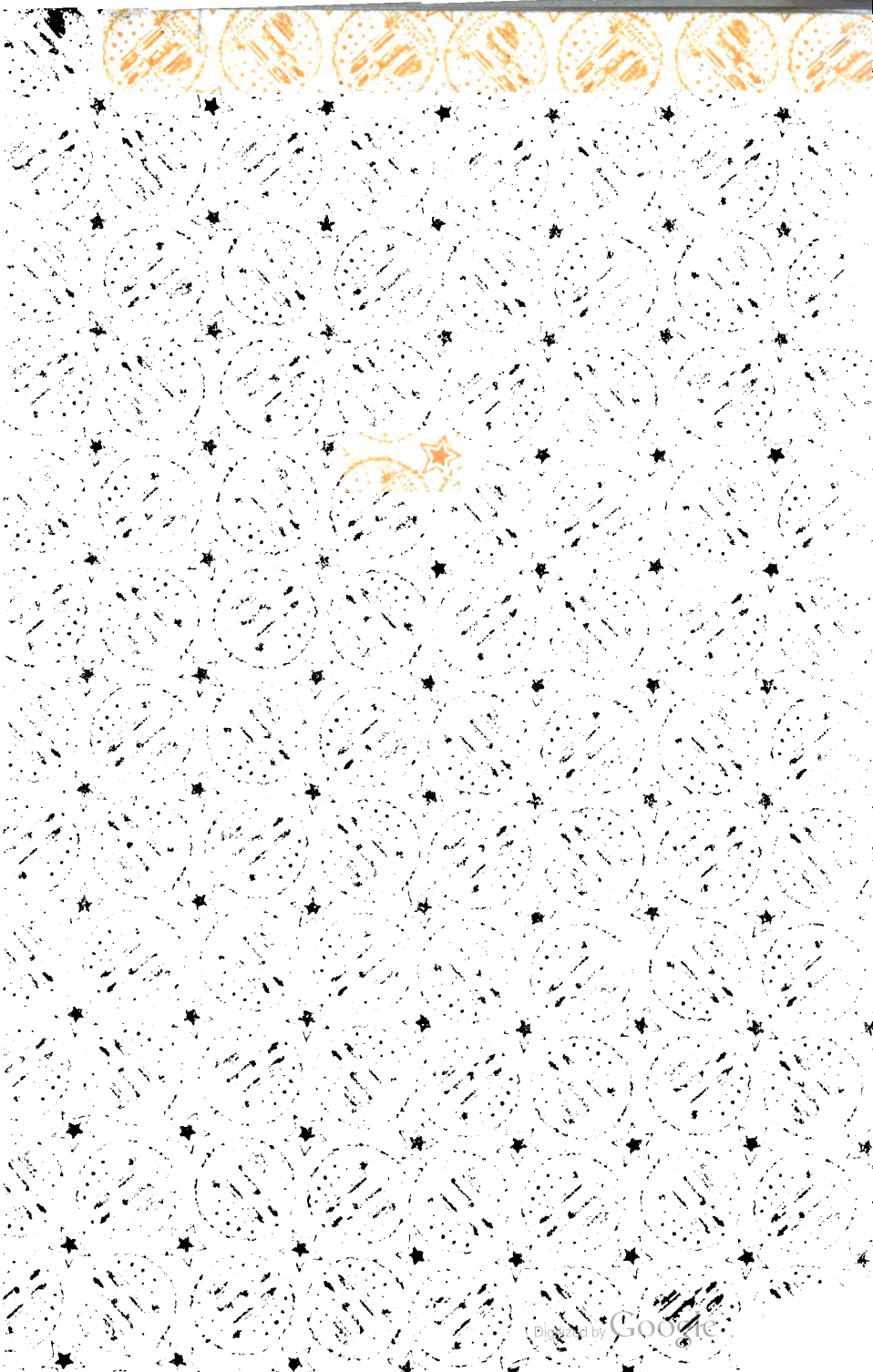
STEELS & ALLOYS FOR SPECIAL PURPOSES

CRUCIBLE STEEL COMPANY OF AMERICA

PITTSBURGH, PA.





STEELS AND ALLOYS

for

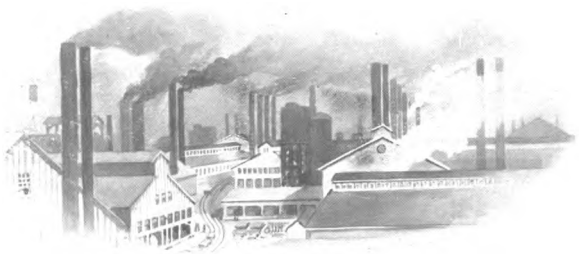
SPECIAL PURPOSES

CRUCIBLE STEEL COMPANY
OF AMERICA

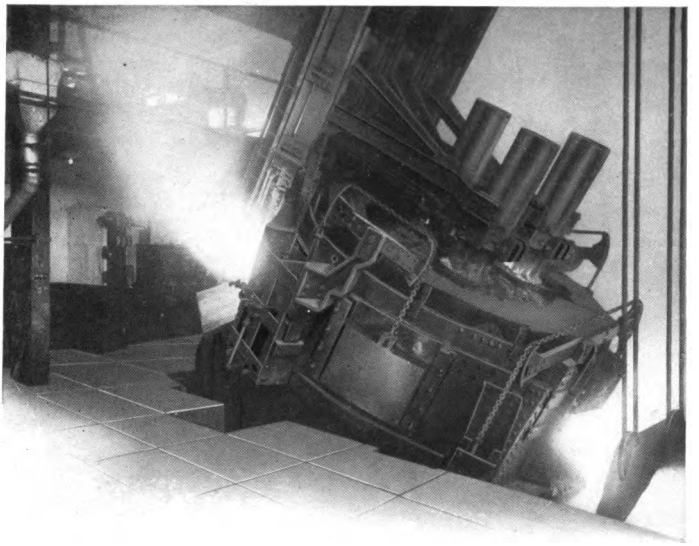
GENERAL OFFICES:
PITTSBURGH, PENNSYLVANIA

PLANTS

Black Diamond (Park) Steel Works	Pittsburgh, Pa.
Crescent Steel Works	Pittsburgh, Pa.
Singer-Nimick Works	Pittsburgh, Pa.
Howe-Brown Works . . .	Pittsburgh, Pa.
La Belle Steel Works	Pittsburgh, Pa.
Anderson-DuPuy Works . .	McKees Rocks, Pa.
Atha Steel Works	Harrison, N. J.
Sanderson Bros. Steel Works . .	Syracuse, N. Y.
Spaulding & Jennings Works . .	Jersey City, N. J.
Aliquippa Steel Works	Aliquippa, Pa.
Norwalk Steel Works	Norwalk, Ohio



CONTENTS

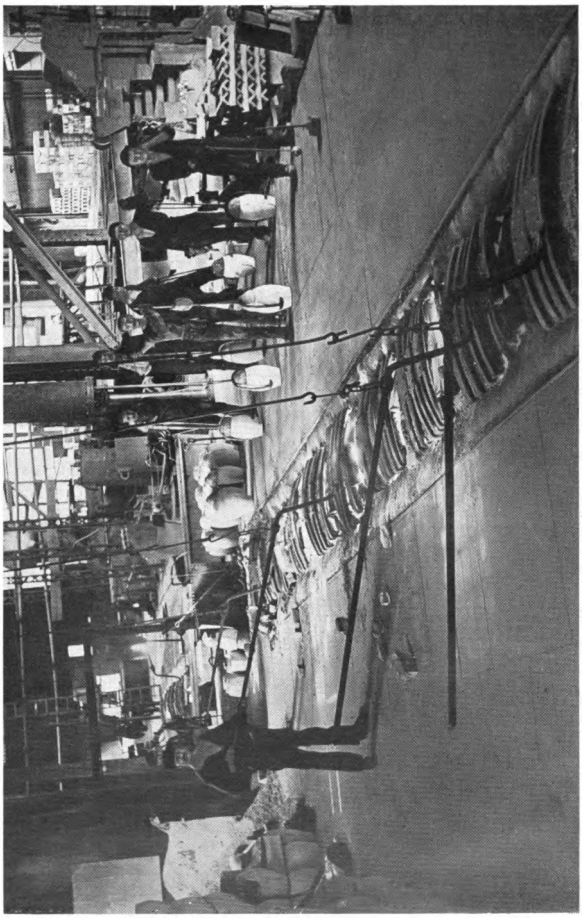


Electric Furnace for Melting Steel

INTRODUCTION

In presenting this edition for your consideration, we would call your attention especially to the interesting and valuable data concerning not only our steels but steel in general. This feature is the result of our Research Department's efforts, and since it is this data in the hands of the skilful expert that proves the key to unlock the gate leading to the road to successful manufacture, this information will prove an aid to the solution of the many difficult problems frequently encountered by the modern engineer. These efforts have not ceased, but are constantly being exercised in the daily propositions presented to us, and it is this that makes more proficient, broadens the experience, and enables us to more efficiently serve you, not only through our steels, the sequence of our studies and efforts, but also through the information thus collected.

The manufacture of steel necessitates melting facilities, fabricating appliances, skill in handling the same, and knowledge of the properties of the specific material being handled. But, on account of its composition, one kind is best melted in an electric furnace, another in the crucible and a third is best made in the open-hearth, either acid or basic. Again, fabrication is best accomplished under a press, or in a rolling mill or under a hammer, or possibly a combination of these. Hence, the desirability of plants equipped as ours, some with crucible melting furnaces, hammers and rolls, others



with open-hearth furnaces, presses and rolls, and still others with electric furnaces or desirable combinations of furnaces, presses, hammers, and rolling mills, so that the commercial manufacture of the most difficult but highly necessary steels and alloys may be successfully accomplished.

Our plants, all under one control, and yet each with its men skilled in working with that equipment peculiar to that works, make us unquestionably the best suited to supply the most perfect as well as the greatest variety of steels and alloys. The most perfect because the individuality of that plant best adapted to the making of the specific steel or alloy, is preserved in its product. The greatest variety because of the facilities obtained through having a number of plants, not mere units as some might believe, each with its distinctive character.

To those interested in the manufacture of aeroplanes, automobiles, electrical, hydraulic and steam appliances, or the development of any specialty, we present the following pages, descriptive of the latest metallurgical efforts in special or alloy steels, and place ourselves at your disposal to assist in the successful commercial manufacture of any product. We would emphasize this word *commercial*, to the import of which we have given most careful consideration in the development of our steels, realizing most fully that the success of a product depends on the one hand, upon its efficiency, on the other, its cost of manufacture; hence our steels cover a range of qualities and prices.

ALLOY STEELS

The October, 1911, Bulletin of the American Iron and Steel Association gives the tonnage of alloy steel ingots and castings made in 1910 as 567,819 tons, an increase of 300 per cent. over 1909. There can be, therefore, no question as to the efficiency of these steels and their wide commercial appreciation.

The character of the alloy steel is determined by the element or elements as the case may be, and the quantity or quantities of the same that may be present, and although it would seem hardly necessary to make the statement, it is only by judicious, scientific selection and proportioning that the desired properties are developed, to the exclusion or suppression of the undesirable, and our high grade alloy steels produced. These include *chrome-nickel*, *chrome-vanadium*, *nickel*, *chrome*, *manganese*, *silicon* and the combinations of these two latter elements known as *silico-manganese* or *mangano-silicon* steels.

DUPLEX GEAR STEEL No. 1

This is the highest type of gear steel. When tempered it possesses the maximum toughness together with the greatest hardness, physical properties which are diametrically opposed to each other and yet essential for the production of the tempered type of gear so much used in automobiles, motorcycles, power boats, etc., where noiseless, light and strong gearing are required.

For such a tough, strong material, this brand of steel machines readily, particularly so, if the cutting tools be ground with a rake a little greater than usually used in cutting ordinary steel, hence the machined gears are more perfect, than those produced from harder and less freely machining steels, and when hardened and drawn will be found to have warped or distorted less than any other steel.

PHYSICAL CHARACTERISTICS

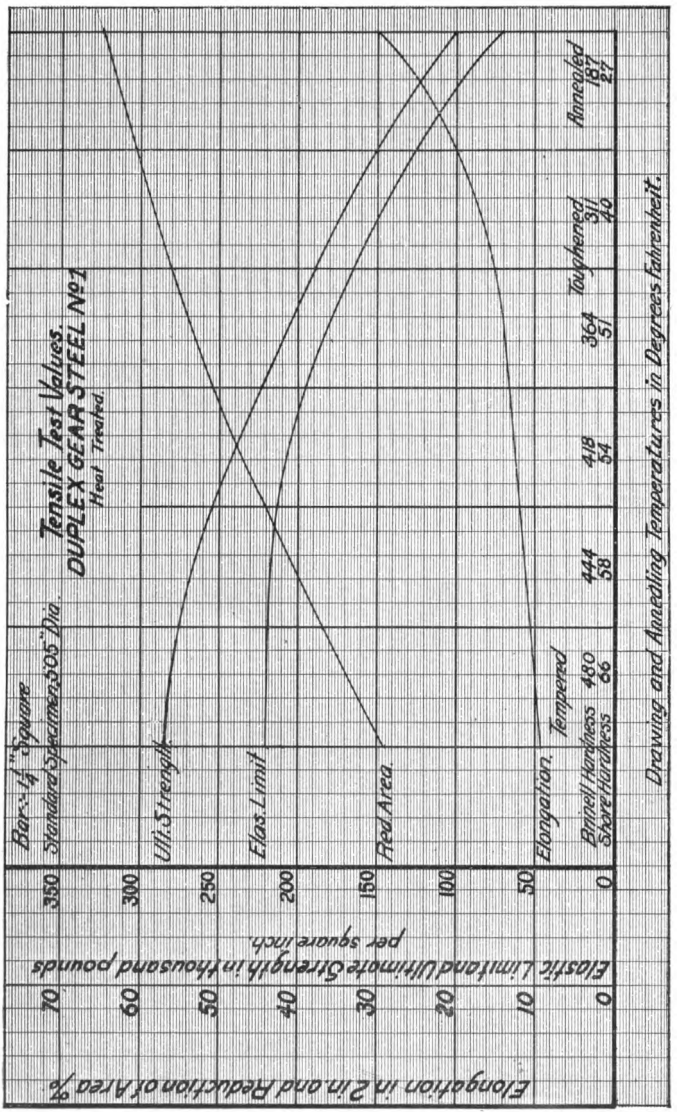
TENSILE TESTS

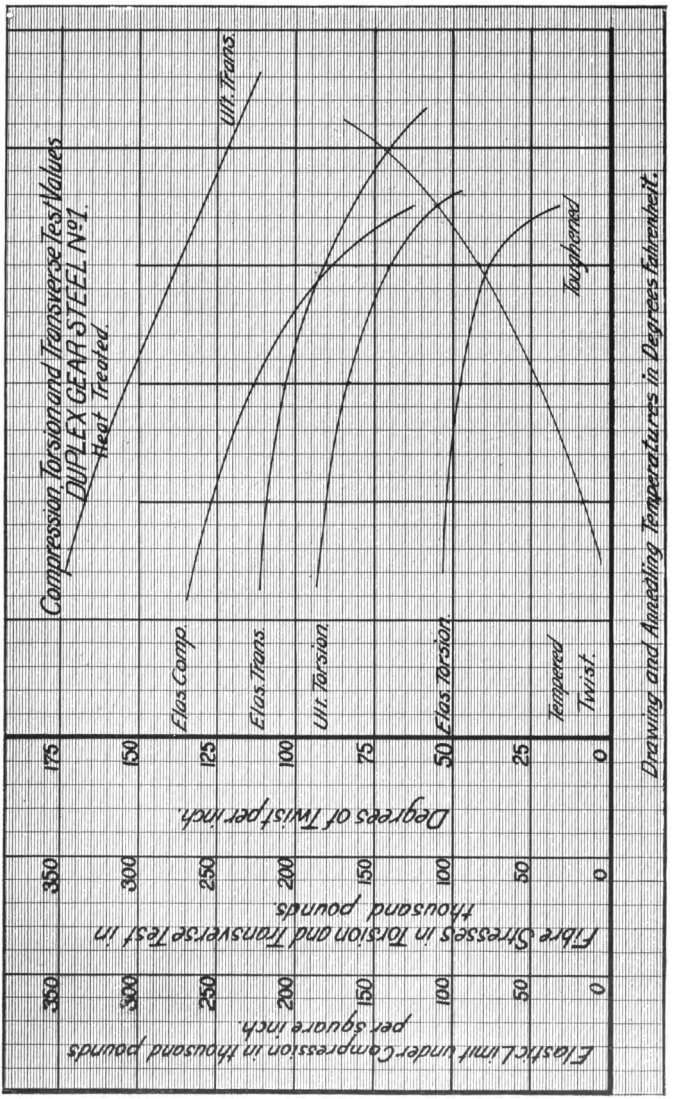
Annealed Specimen		Tempered Specimen
65,000	Elastic limit, pounds per square inch	220,000
90,000	Tensile strength, pounds per square inch	285,000
30%	Elongation in two inches	10%
65%	Reduction of area	35%

BRINELL HARDNESS VALUES

Annealed Specimen	Tempered Specimen
156–187	430–480

We will supply forgings of this steel, guaranteeing them to be in the best physical condition, free from seams, flaws, etc., and with all the potential properties of the steel unimpaired, so that the subsequent simple treatment which we prescribe will fully develop the latent qualities of this highest grade material.





Duplex Gear Steel No. 1 when toughened instead of tempered is remarkably strong and exceedingly tough. It is therefore well adapted to the manufacture of light shafting which must transmit the maximum amount of torque, and is especially recommended for live axles, propellor shafts, crank shafts in automobiles, motor boats and motorcycles.

PHYSICAL CHARACTERISTICS

TENSILE TEST

	Toughened Specimen
Elastic limit, pounds per square inch	140,000
Tensile strength, pounds per square inch	170,000
Elongation in two inches	17%
Reduction of area	58%

BRINELL HARDNESS VALUE

Toughened specimen	311–364

In this condition the steel can just be machined. It is therefore advisable to do all the rough machining on the annealed forging, treat so as to impart the necessary properties, then finish machine to the required dimensions.

We would call your attention in particular to the effects of heat treatment as shown by the *tensile*, *torsion transverse* and *compression* diagrams, wherein are brought out the other physical characteristics of this remarkable steel.

DUPLEX C. H. STEEL No. 1

Automobile manufacturers use either a case-hardened or a tempered gear; the latter seems to be in more general use, particularly in cars of the higher classes. However, to meet the requirements of those wishing the former type of gear, we recommend this brand as the acme of steels for this purpose. It can readily be carbonized, and the results are well worth the small extra care required to produce the best case-hardened gears.

It is of the same type as Duplex Gear Steel No. 1, but of course of a lower carbon to meet the requirements necessary for case-hardening.

Not only is this steel suitable for gear manufacture, but also for the making of any other case-hardened parts which must be exceedingly strong, hard and tough; for example, wrist pins, gudgeon pins, shafts, etc., for aeroplanes, automobiles, motors and machinery of various kinds.

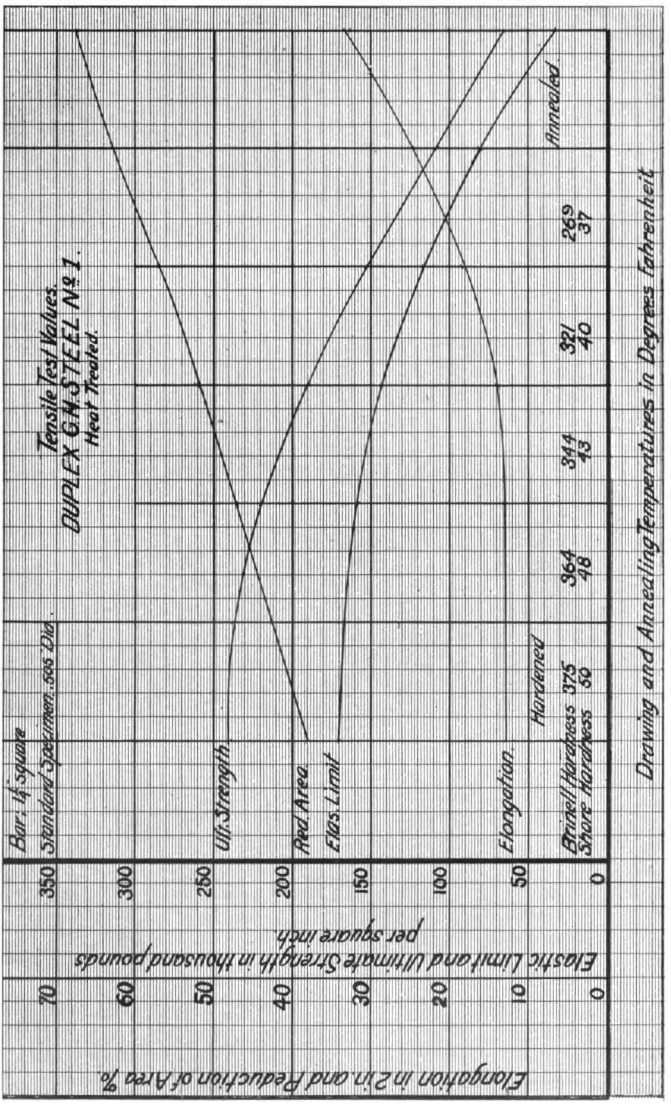
PHYSICAL CHARACTERISTICS

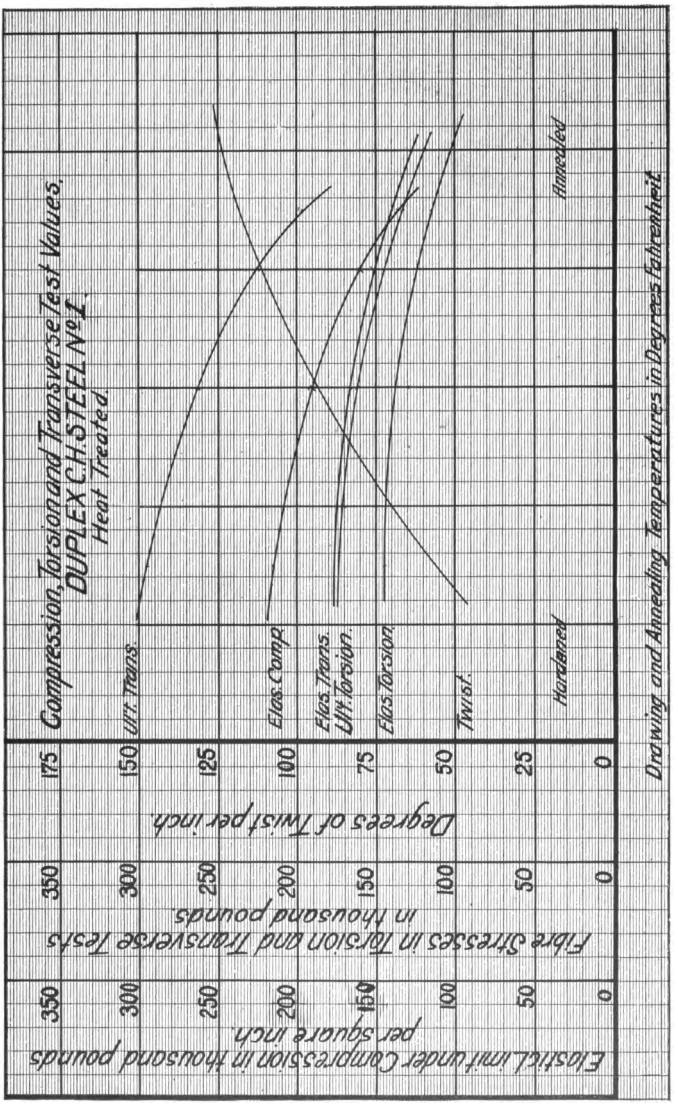
TENSILE TESTS

Forging Specimen		Core of Case-hardened Specimen
55,000	Elastic limit, pounds per square inch . .	170,000
85,000	Tensile strength, pounds per square inch	195,000
24%	Elongation in two inches	13%
40%	Reduction of area	45%

BRINELL HARDNESS VALUE

Core of Case-carbonized Specimen	321-375





DUPLEX GEAR STEEL No. 2

Like its predecessor, to which it is second, this brand is intended primarily for the manufacture of tempered gears and possesses all the desirable attributes of Duplex Gear Steel No. 1, but to a lesser degree except in the matter of hardness in which it excels. This latter feature makes it a very good material from which to make clash gears, especially if they be designed with stub teeth.

PHYSICAL CHARACTERISTICS

TENSILE TESTS

Annealed Specimen		Tempered Specimen
64,000	Elastic limit, pounds per square inch . .	205,000
89,000	Tensile strength, pounds per square inch .	275,000
25%	Elongation in two inches	6%
64%	Reduction of area	20%

BRINELL HARDNESS VALUES

Annealed Specimen	Tempered Specimen
179–196	460–512

It does not present great difficulties to the ordinary drop-forger, who, with a moderate degree of care, can most efficiently handle it.

If this Duplex Gear Steel No. 2 be subjected to a toughening process, it may be used for shafts, crank shafts, axles, etc. It is not, however, as strong and tough as Duplex Gear Steel No. 1, nor does it machine with quite the same degree of ease, nevertheless it is a most desirable steel.

DUPLEX GEAR STEEL No. 2

(Continued)

PHYSICAL CHARACTERISTICS

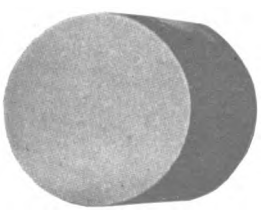
TENSILE TEST

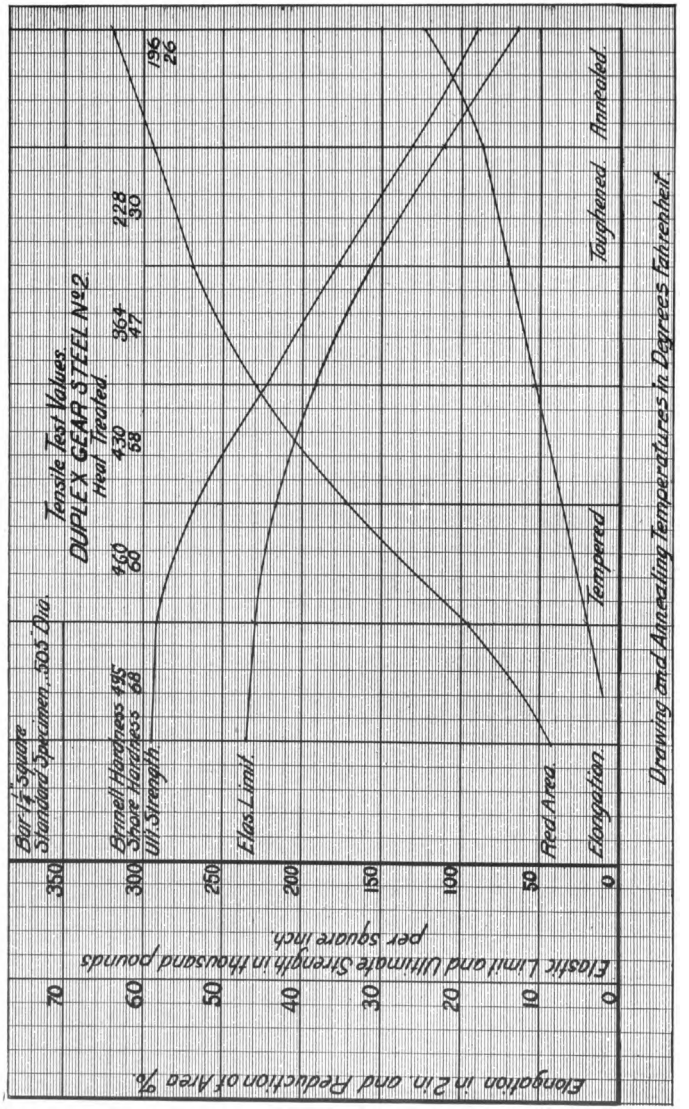
	Toughened Specimen
Elastic limit, pounds per square inch	110,000
Tensile strength, pounds per square inch	125,000
Elongation in two inches	18%
Reduction of area	55%

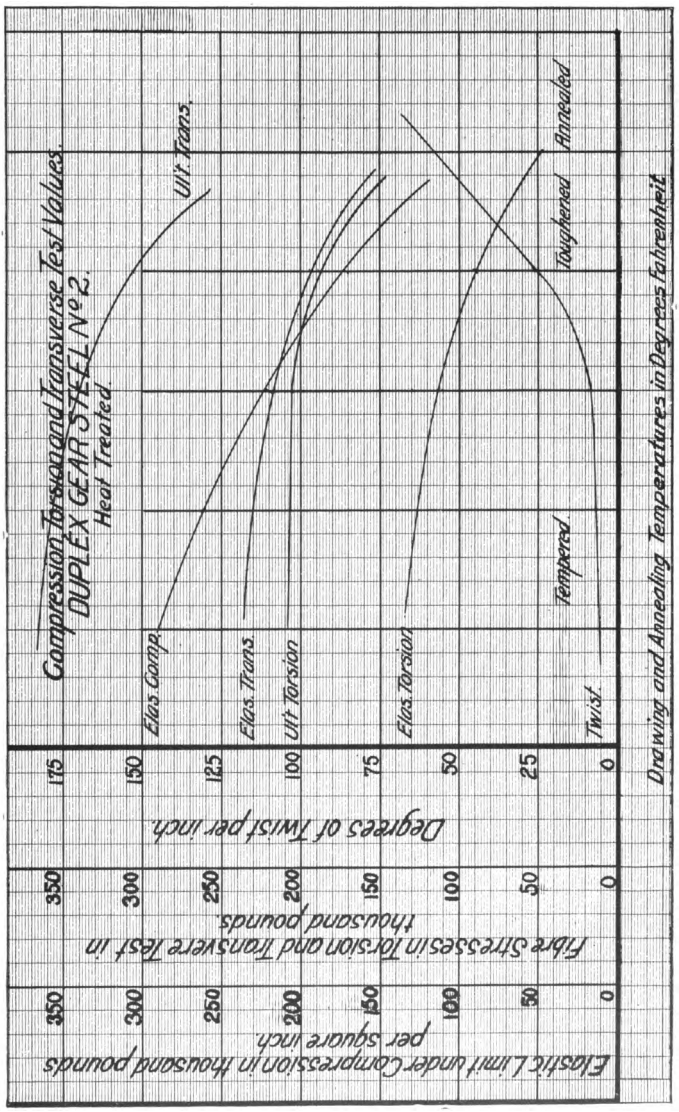
BRINELL HARDNESS VALUE

Toughened specimen	311-332

Aside from the manufacture of gears, crank shafts, axles, etc., this steel under varying conditions of heat treatment, as a consideration of the curves descriptive of its physical characteristics to be found on next two pages will show, has a wide adaptability. For the pistons in hydraulic rams or heavy presses it is just the thing.







DUPLEX C. H. STEEL No. 2

This steel differs from the gear steel of this general name only in respect to its carbon content which is lower to permit of case-hardening. It is very much like 3½ per cent. nickel steel in its machining and forging properties. However, it excels this latter mentioned material in that the core and case are more strong and tough, and it exhibits the same characteristics in whatever plane the test specimen be located, which indicates the thorough homogeneity of this product.

It is applicable to the manufacture of any of the parts referred to when we were discussing Duplex C. H. Steel No. 1.

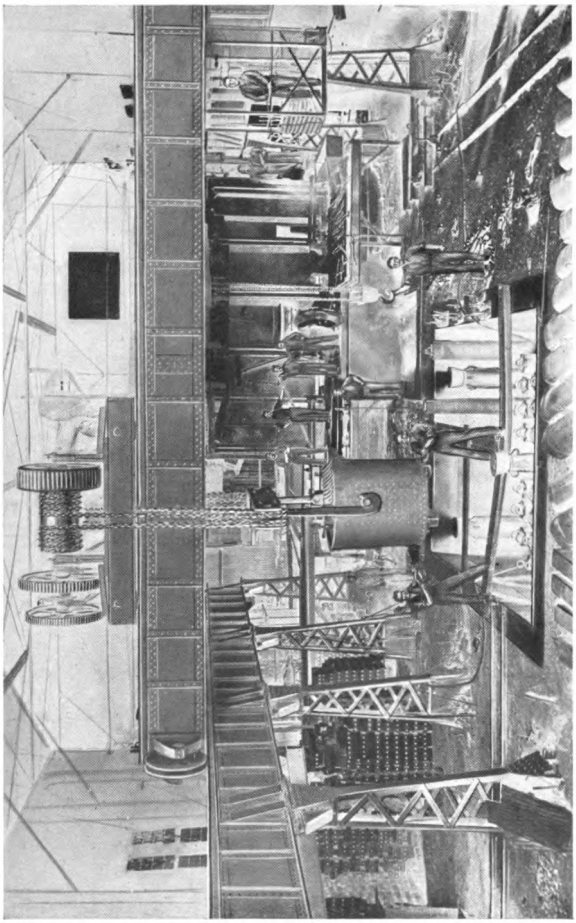
PHYSICAL CHARACTERISTICS

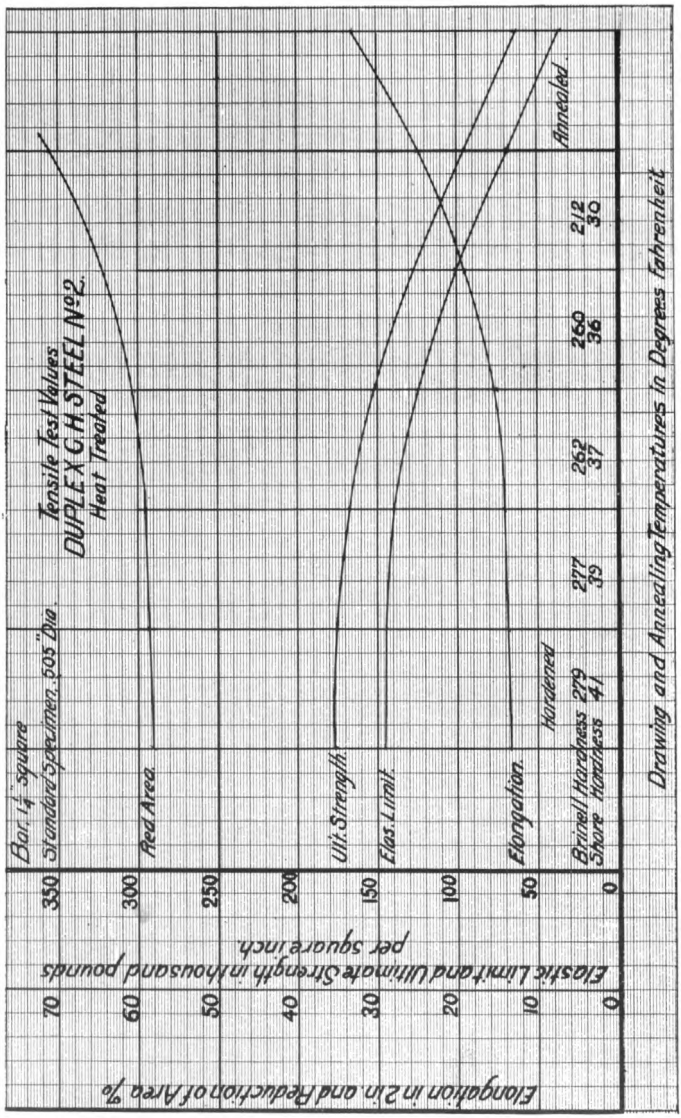
TENSILE TEST

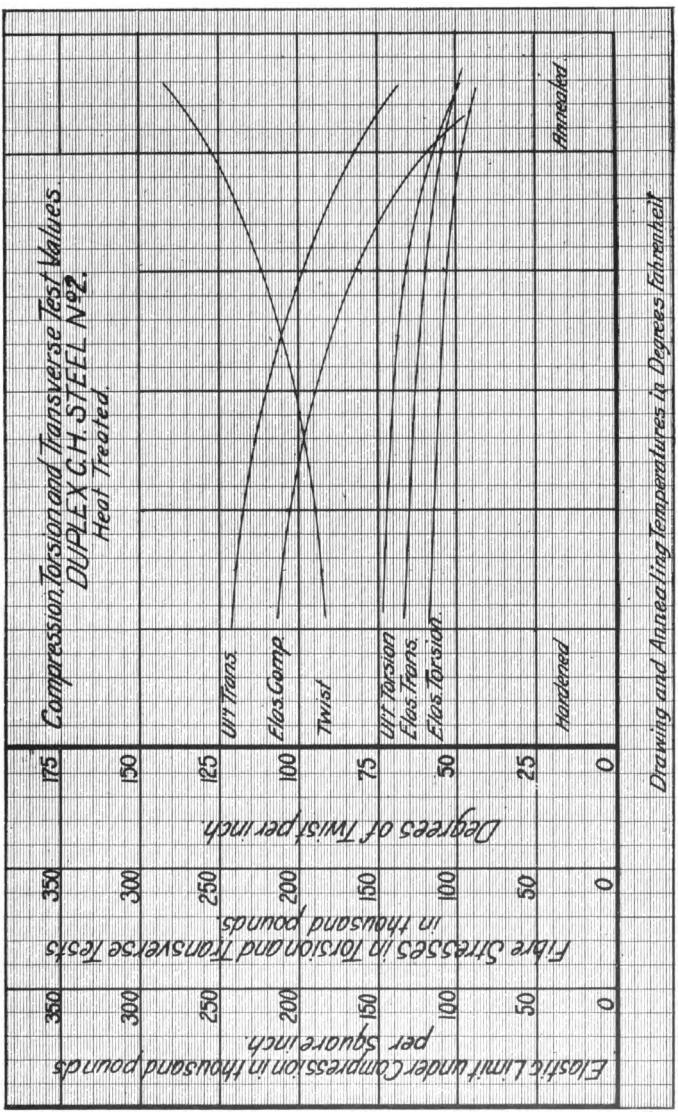
	Core of Case-hardened Specimen
Elastic limit, pounds per square inch	140,000
Tensile strength, pounds per square inch	165,000
Elongation in two inches	12%
Reduction of area	50%

BRINELL HARDNESS VALUE

Core of Case-carbonized Specimen	260–302







ALVA DUPLEX FORGING STEEL

This brand represents the highest grade of the Chrome-vanadium steels, and is the result of a thorough and complete study of the part played by these two elements in combination with each other. The steel machines well and can readily be manipulated by those familiar with such operations. It is adapted to such parts as axles, shafts, crank shafts, bolts, pins, piston rods, etc., in automobiles, motors and light, small power plants of great horse-power, where lightness and strength are of first importance.

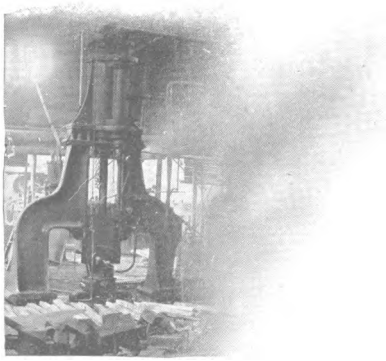
PHYSICAL CHARACTERISTICS

TENSILE TESTS

Forging Specimen		Treated Forging
51,000	Elastic limit, pounds per square inch . .	112,000
75,000	Tensile strength, pounds per square inch.	130,000
25%	Elongation in two inches	18%
45%	Reduction of area	52%

BRINELL HARDNESS VALUES

Forging Specimen	Treated Specimen
179–196	293–321



ALVA DUPLEX C. H. STEEL

The remarks regarding the forging steel apply largely to this case-hardening brand of steel. It machines well and can be handled readily by any one familiar with case-carbonizing and treating steel. We recommend this brand for case-carbonized gearing, and all those small pieces where toughness and hardness are to be combined to meet the conditions of service.

PHYSICAL CHARACTERISTICS

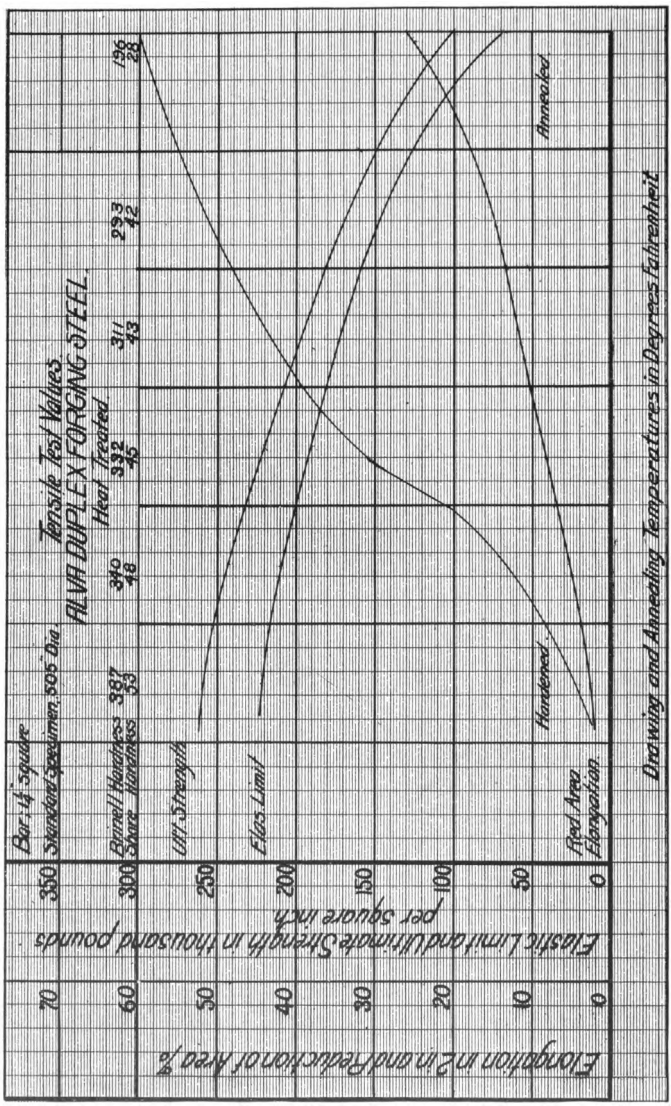
TENSILE TESTS

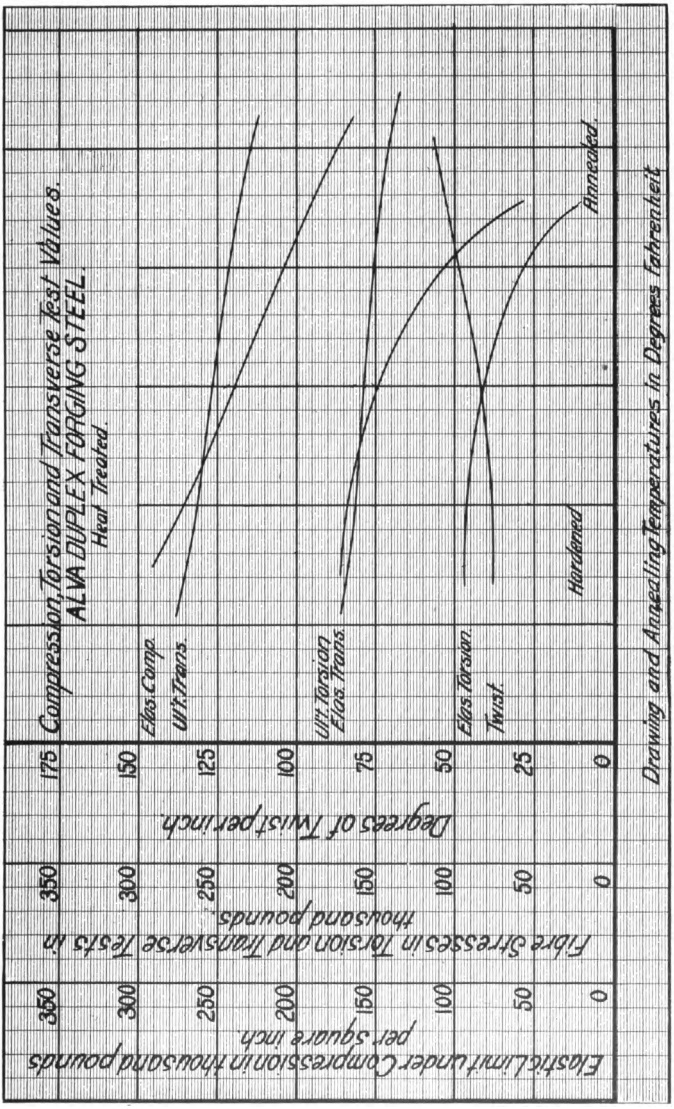
Forging Specimen		Core of Case-hardened Specimen
45,000	Elastic limit, pounds per square inch . .	140,000
73,000	Tensile strength, pounds per square inch.	170,000
30%	Elongation in two inches	12%
65%	Reduction of area	50%

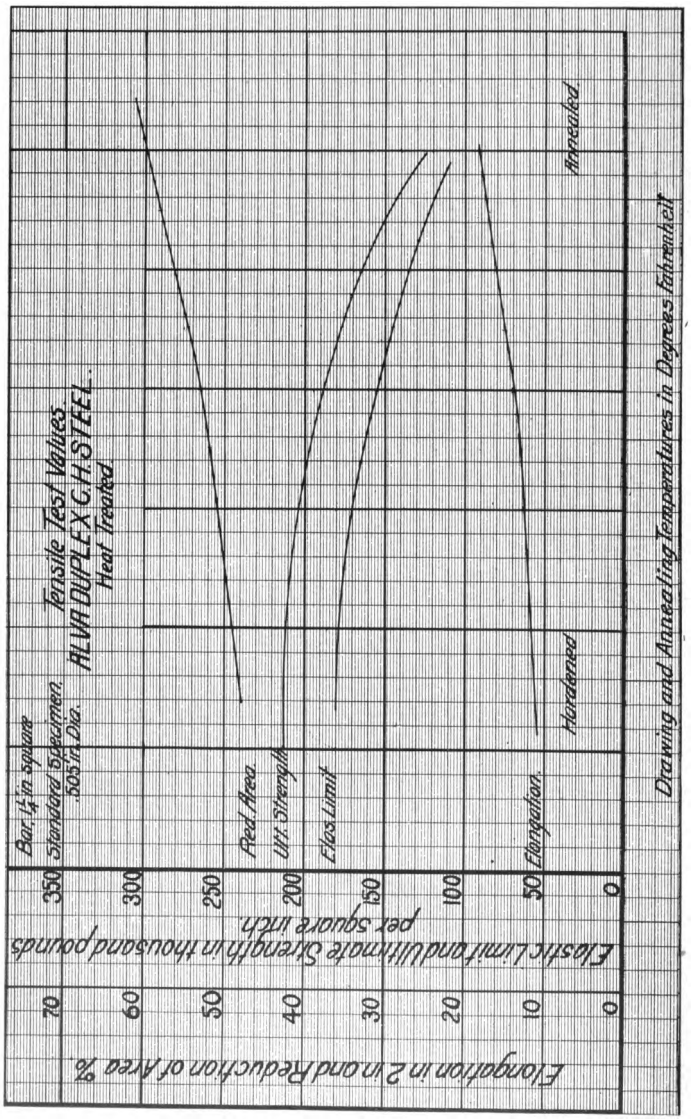
BRINELL HARDNESS VALUES

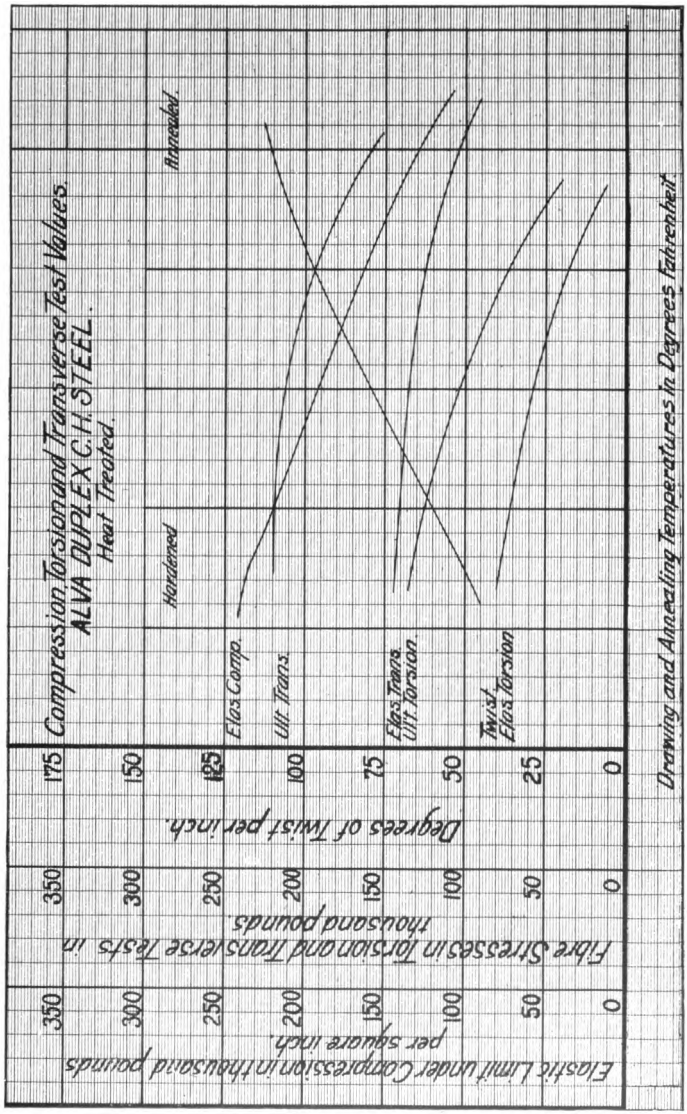
Forging Specimen	Core of Case-hardened Specimen
163–196	260–302

The accompanying diagrams show the possibilities of these Alva Duplex Steels.









APPLICATION OF TENSILE AND STRESS DIAGRAMS

That steel showing the highest ultimate strength, elastic limit, and stress values, either under tension, compression, shearing or torsion, together with the desired degree of toughness, as measured by the elongation, reduction of area, degree of deflection, or angle of twist, permits of lighter construction through a reduction of section; or if the section be maintained, offers a greater margin of safety. In automobile construction, both of these features are especially desirable, and in many other instances they are absolutely necessary to success. These diagrams become of great value in clearly presenting these features, as the following will illustrate:—

Upon referring for instance, to the tensile test diagrams and the curve marked, "Ul't Strength," it will be seen from the values in the margin, that the maximum figures are those under the heading "Hardened," on the left, and the minimum figures on the right under "Annealed." Between these extremes, the intermediate ultimate strengths are the result of heating the hardened specimens to intermediate temperatures, that is to say, temperatures gradually increasing from those employed in tempering to those used in annealing, and the values can be quickly ascertained by following the horizontal line from its intersection with the curve to the margin. It will be noted that as the ultimate strength and elastic limit decrease, the elongation and reduction of area increase, and the values of the same corresponding to any ultimate strength are determined by the intersection of the curves with the vertical line. Thus, referring to Duplex Gear Steel No. 1 Tensile Test Diagram, upon following the 250,000 lbs. per square inch horizontal line to the intersection with the curve of ultimate strength, then along the vertical line to where it meets the curves of elastic limit, reduction of area, and elongation, the values of these are read off by following out the horizontal line to the left margin:—

Ultimate Strength . .	250,000 lbs. per square inch.
Elastic Limit	210,000 lbs. per square inch.
Elongation	11.2%
Reduction	45.5%

Having determined through experience or otherwise that 12% elongation and 45% reduction of area represents the minimum degree of toughness permissible, and steel with the maximum ultimate strength and elastic limit is desired, we turn to our diagrams and find the following:—

	Ult. Strength lbs. per sq. in.	Elast. limit lbs. per sq. in.	Elongation %	Reduction of Area %
Duplex Gear Steel No. 1 . .	250,000	210,000	12.0	45.5
Duplex Gear Steel No. 2 . .	205,000	178,000	12.0	49.0
Alva Duplex Forging Steel . .	192,000	168,000	12.0	45.0
Sanderson Nickel Forging Steel	238,000	195,000	12.4	45.0
Simplex Forging Steel . .	152,000	126,000	12.6	45.0

Of course, the whole story of adaptability is not told in the tensile test values, inasmuch as hardness, wearing properties, warpage in the heat-treating operation, and other features characteristic of each individual steel, must be considered in selecting steels for any specific purpose.

SANDERSON NICKEL FORGING STEEL

This is the highest type of this most widely used alloy steel and being made in small ingots is therefore remarkably free from the objectionable features which characterize 3½ per cent. nickel steel made at plants where the motto is "*tonnage.*" It is suited for the manufacture of axles, shafts, automobile steering knuckles, connecting rods, etc.

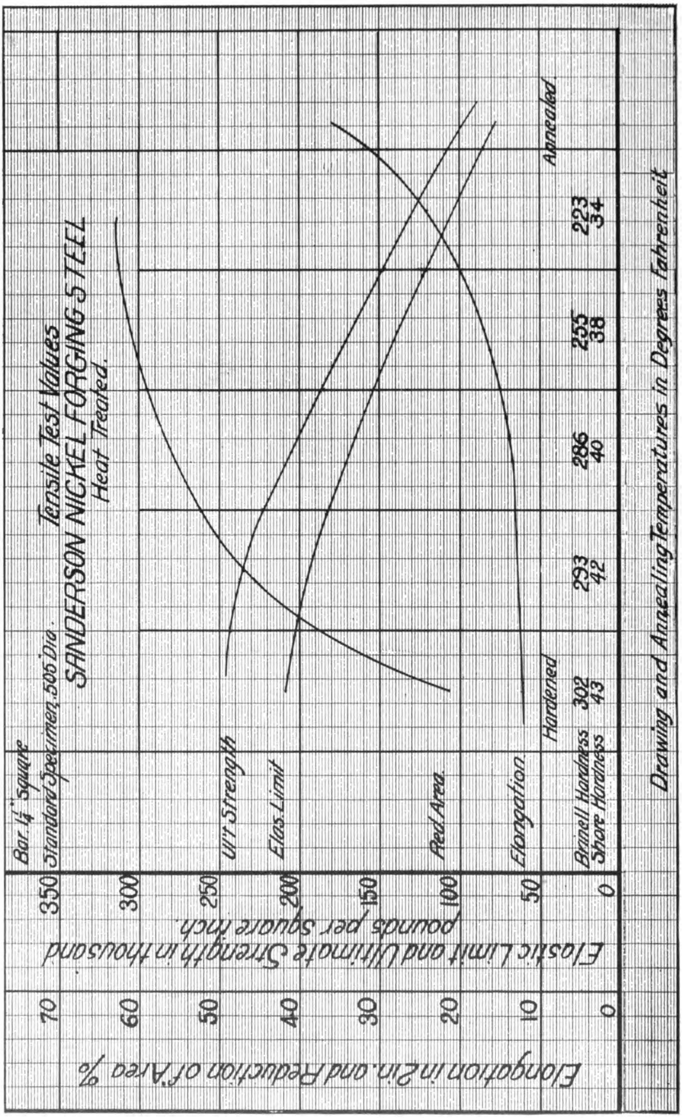
PHYSICAL CHARACTERISTICS

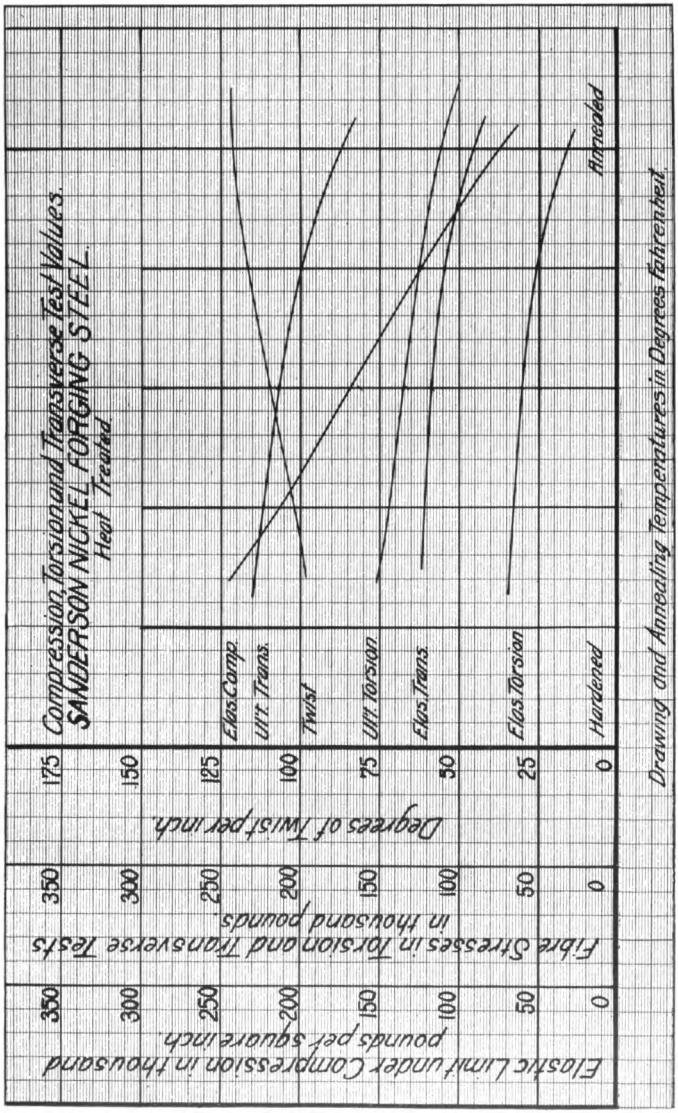
TENSILE TESTS

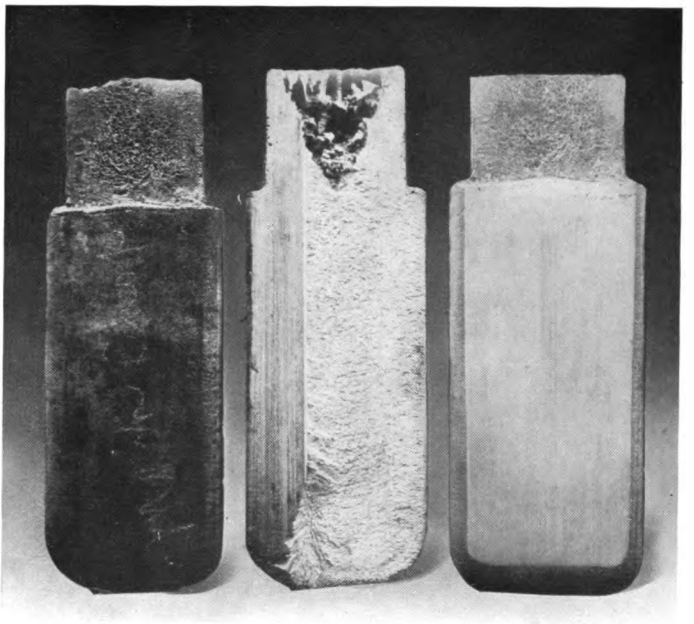
Forging Specimen		Treated Specimen
63,000	Elastic limit, pounds per square inch . .	90,000
103,250	Tensile strength, pounds per square inch .	127,000
17%	Elongation in two inches	21%
35%	Reduction of area	57%

BRINELL HARDNESS VALUES

Forging Specimen	Treated Specimen
166	223–293


Tensile Test Values
SANDERSON NICKEL FORGING STEEL
Heat Treated.
Bar 1¼" Square
Standard Specimen .505 Dia.
Ul't Strength
Elas. Limit
Red Area.
Elongation
Brinell Hardness
Shore Hardness
Hardened
302
43
293
42
286
40
255
38
223
34
Annealed
Drawing and Annealing Temperatures in Degrees Fahrenheit
Elastic Limit and Ultimate Strength in thousand pounds per square inch.
350
300
250
200
150
100
50
0
Elongation in 2 in. and Reduction of Area %
70
60
50
40
30
20
10
0





Ingots of Sanderson Nickel Forging Steel

Machined parts made from this most uniform 3½% Nickel Steel are exceedingly tough and strong when heat-treated, as the values derived from the diagram will show. We can supply this steel in treated and machinable bars to show any elastic limit up to 90,000 pounds per square inch, when the machined parts need but be assembled.

SANDERSON NICKEL C. H. STEEL

Like all our C. H. steels it is low in carbon, since it is intended primarily for case-hardening, to which process it responds readily, taking on a very uniform case.

For small parts to have a hard exterior, in order to withstand wear and with a tough core or center to offer great resistance to shock, this brand of 3½ per cent. nickel steel is well adapted. It possesses all the merits of quality just related under Sanderson Nickel Forging Steel and is in fact the best of all the 3½ per cent. nickel steels obtainable.

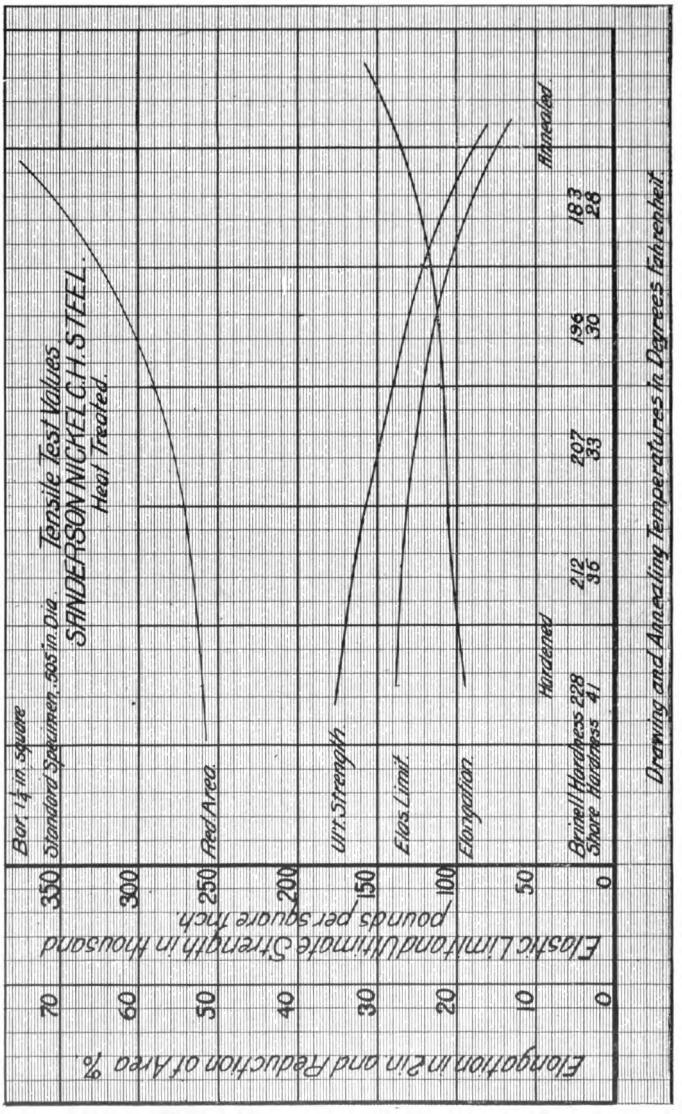
PHYSICAL CHARACTERISTICS

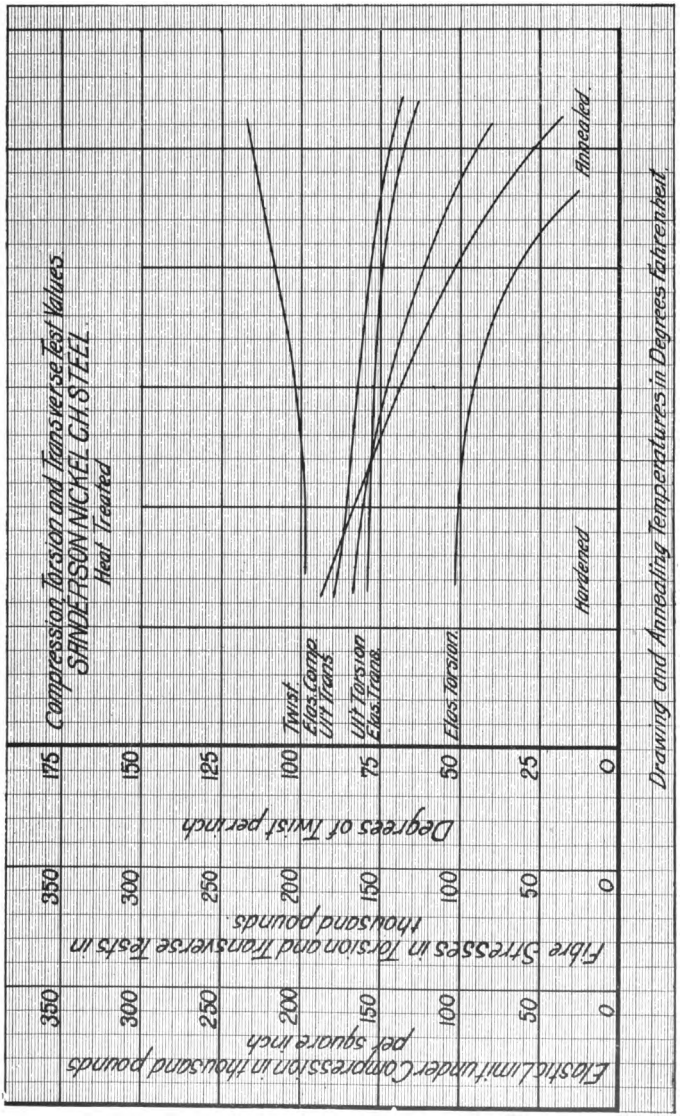
TENSILE TESTS

Forging Specimen		Core of Case-hardened Specimen
43,000	Elastic limit, pounds per square inch	95,000
75,000	Tensile strength, pounds per square inch	110,000
25%	Elongation in two inches	18%
40%	Reduction of area	60%

BRINELL HARDNESS VALUES

Forging Specimen	Core of Case-hardened Specimen
167	196–262





STANDARD NICKEL FORGING STEEL

This is the 3½ per cent. nickel steel used by the United States Government for gun tubes and gun parts. Like all forging steels, it is of a carbon content higher than the case-hardening grades, in order that it may respond more effectively to the heat treatment necessary in the case of all alloy steels, if full value is to be obtained from them. This brand is much used for axles, shafts, steering knuckles, etc., in automobiles and in the construction of engine parts.

PHYSICAL CHARACTERISTICS

TENSILE TEST

	Treated Forging
Elastic limit, pounds per square inch	85,000
Ultimate strength, pounds per square inch	120,000
Elongation in two inches	20%
Reduction of area	50%

BRINELL HARDNESS VALUE

Treated Specimen	302

STANDARD NICKEL C. H. STEEL

This is a very efficient 3½ per cent. nickel steel, such as is in general use, and is standard with the United States Government. It is low in carbon, to permit of case-hardening, machines easily and is well adapted to engine, motor and machine parts, both large and small. When case-hardened, it offers a hard-wearing surface with a tough core, and when given a toughening treatment it makes parts especially resistant to vibration, shock and alternate stresses.

PHYSICAL CHARACTERISTICS

TENSILE TESTS

Forging Specimen		Toughened Specimen
42,000	Elastic limit, pounds per square inch	55,000
68,000	Tensile strength, pounds per square inch	80,000
23%	Elongation in two inches	25%
43%	Reduction of area	60%

BRINELL HARDNESS VALUES

Forging Specimen	Toughened Specimen
162	262

SIMPLEX FORGING STEEL

This is an ideal steel for the manufacture of all parts which are drop-forged and afterwards treated to develop in them a degree of strength such as would be obtained from a similar carbon temper 3½ per cent. nickel steel. It is the equal in physical properties of 3½ per cent. nickel steel without possessing the objectionable tendency to laminate, which characterizes the latter. In other words, it is more homogeneous in texture throughout. The superior forging and machining properties commend this brand to all automobile manufacturers making the cheaper cars, and to all those where price is a large factor in the construction.

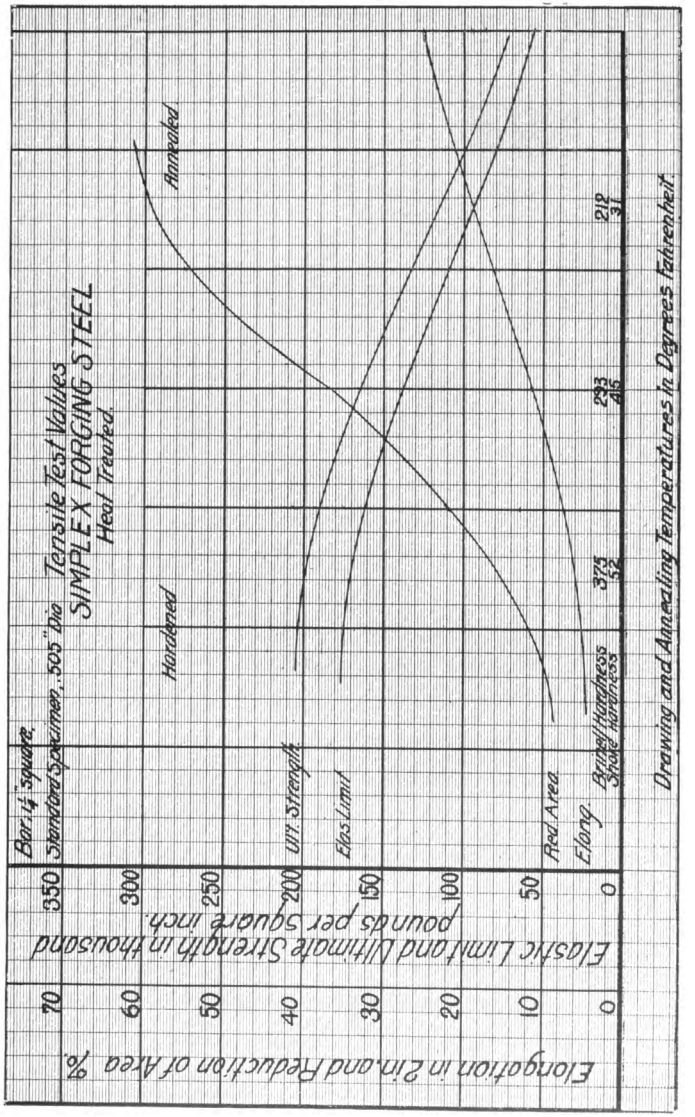
PHYSICAL CHARACTERISTICS

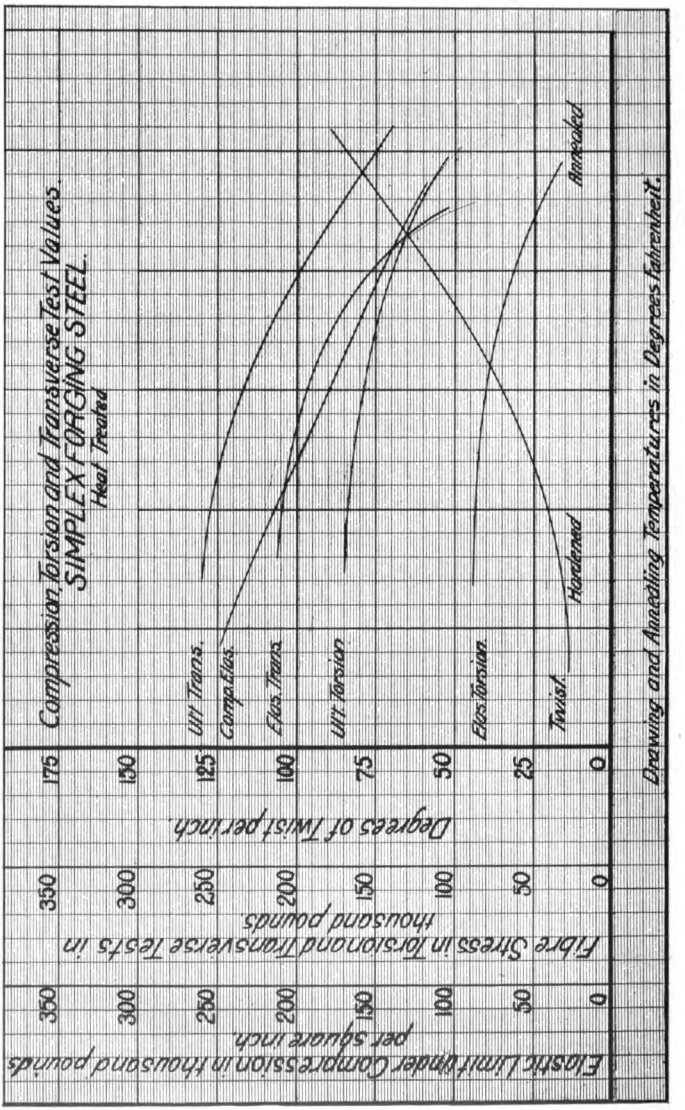
TENSILE TEST VALUES

Forging Specimen		Treated Specimen
50,000	Elastic limit, pounds per square inch . .	111,000
75,000	Tensile strength, pounds per square inch .	130,000
24%	Elongation in two inches	17%
40%	Reduction of area	45%

BRINELL HARDNESS VALUES

Forging Specimen	Treated Specimen
183–202	212–293





SIMPLEX C. H. STEEL

We strongly recommend this brand of steel for case-hardened parts in place of 3½ per cent. nickel steel. It lends itself to all operations readily, is thoroughly reliable, and can be safely quenched in water or oil in the treating processes. Being so uniform in composition and so exceedingly homogeneous, it makes good case-hardened gears, pins, bolts, and any of those parts of small section which require hard wearing-surfaces and toughness.

PHYSICAL CHARACTERISTICS

TENSILE TESTS

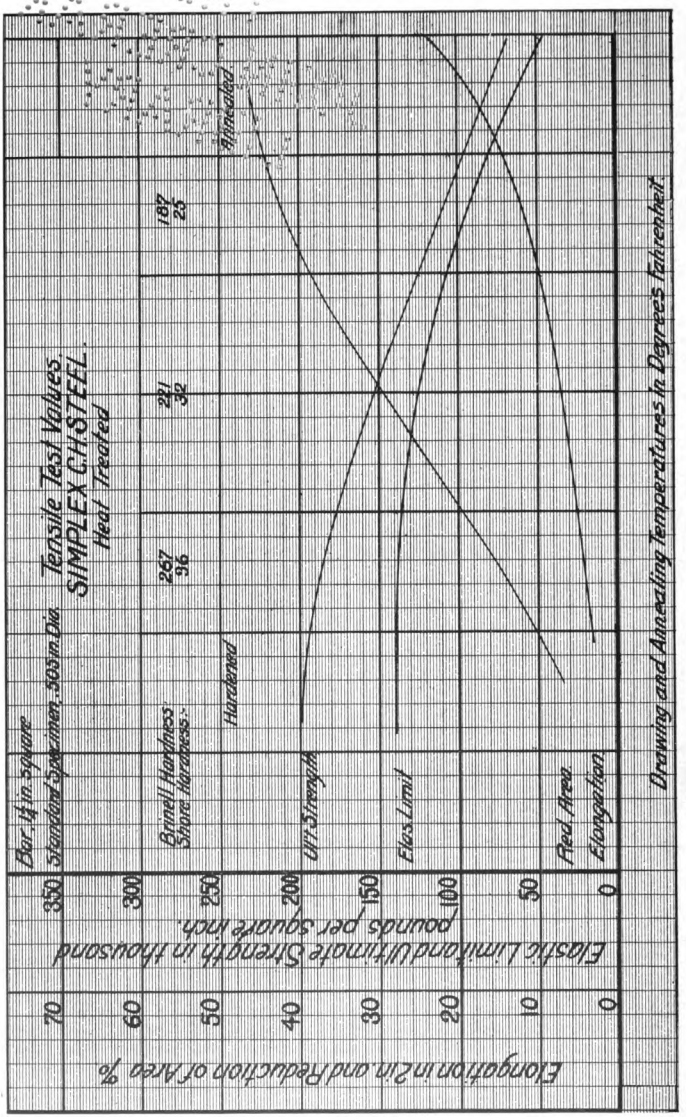
Forging Specimen		Core of Case-hardened Specimen
40,000	Elastic limit, pounds per square inch . .	80,000
70,000	Tensile strength, pounds per square inch .	90,000
23%	Elongation in two inches	16%
48%	Reduction of area	45%

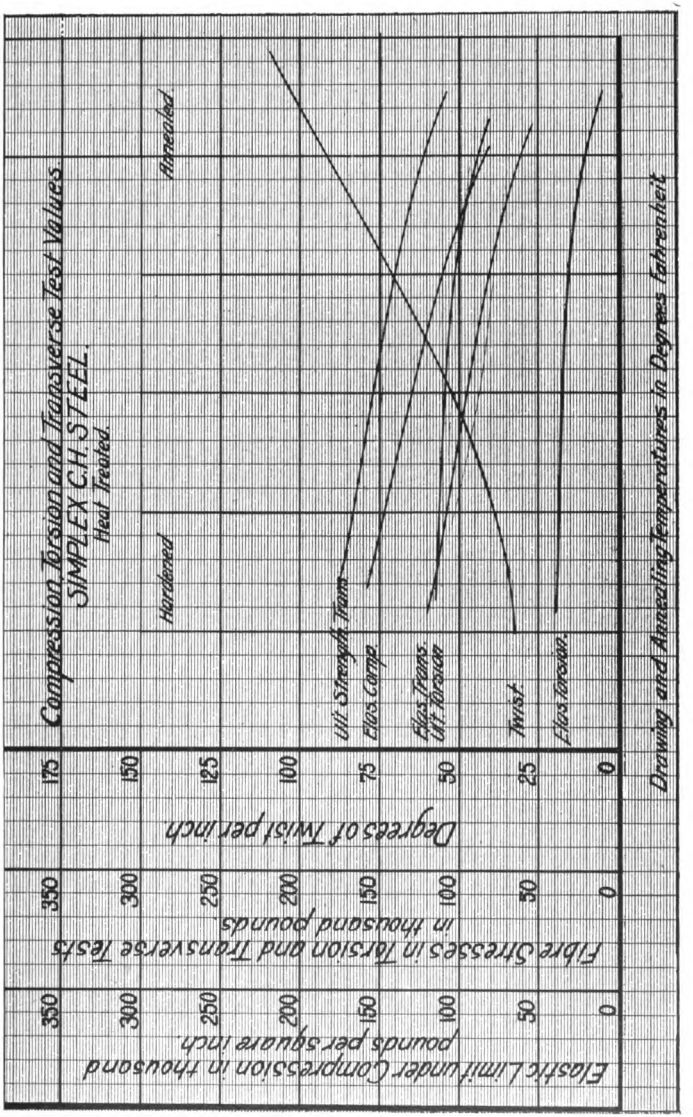
BRINELL HARDNESS VALUES

Forging Specimen	Core of Case-hardened Specimen
163–183	221–267

The values shown by these diagrams, expressing the possibilities of our *Simplex Steels*, show the same to be wonderful material and from the price point of view they are extraordinary.

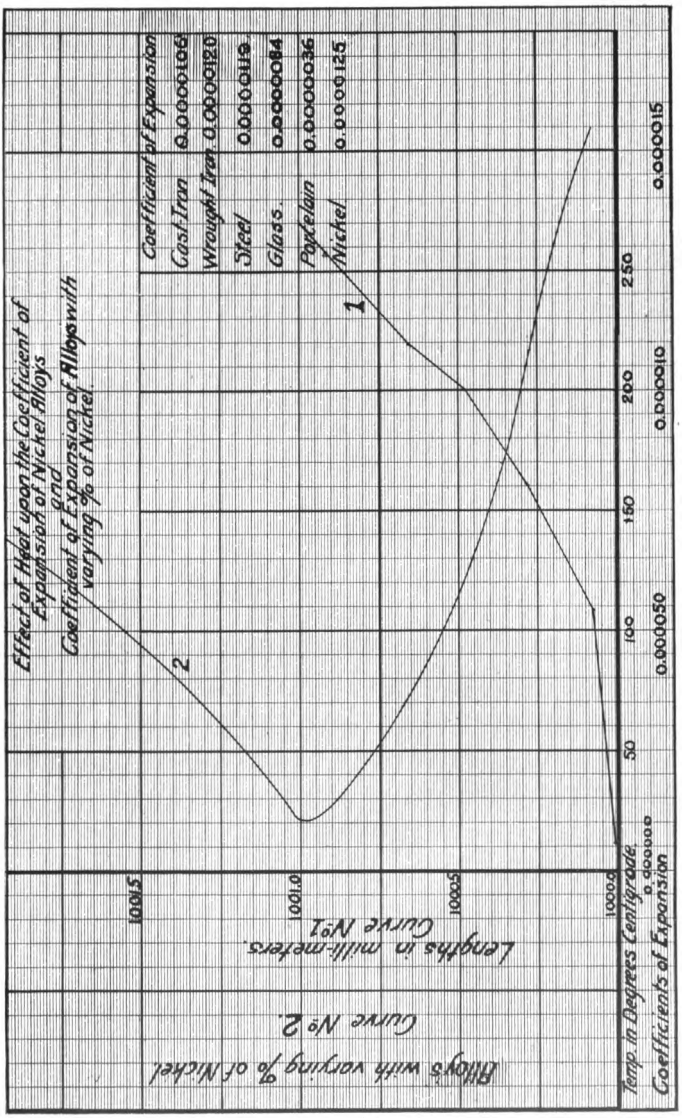
In composition, our *Simplex Steels* are the most uniform and dependable of any to be found at similar prices.





HIGH NICKEL ALLOYS

These we manufacture in a number of grades for a variety of purposes such as gas engine valves, turbine blades, ignition tubes, spark plugs and similar parts requiring a strong, tough, non-corrosive material, or those with a definite coefficient of expansion. The nickel content varies from 5 to 95 per cent. and the effectiveness of the alloy to resist the corrosive action of gases and liquids increases with the percentage of nickel. The 5 per cent. alloy makes a very much stronger and tougher valve than the 30 and higher per cent alloys and has the merit of being cheaper but it is not so resistant to corrosive agents. The diagram on opposite page shows the coefficient of expansion of some of these alloys together with a curve illustrating the effect of temperature upon the same, and this data to the skilled and observing engineer will suggest possible applications which will obtain for him the sought-for results.



A WORD AS TO BALL AND BALL RACE STEEL

Appreciating that the cardinal attributes of the superior ball race steel are hardness and plasticity, two opposing qualities, just as we have hardness and toughness in gears, we have developed all our ball race and ball steels with the idea of combining these properties to the greatest degree in the hardened parts. Hardness to withstand the loads and offer resistance to abrasion, plasticity to endure the slippage of the balls, due to the mechanical construction of the bearing. This plasticity prevents the sluffing off of the surface, producing thereby a spot from which further wear readily spreads.

CHROME BALL RACE STEEL

With the above ideas in mind, we have perfected this brand of steel. When annealed, in which condition we supply it, it machines readily, and when hardened it combines hardness, strength and plasticity to the maximum degrees. Furthermore, it is not a sensitive steel, possessing quite a range in which it may be successfully hardened.

SHORE SCLERESCOPE HARDNESS VALUE
85-90

We recommend this steel as the climax for the manufacture of ball races, cups, cones and any other parts where the aforementioned qualities may be desired to the highest degree.

DUPLEX CONE STEEL

This is a very excellent chrome steel at a moderate price, superior to any carbon tool steel, inasmuch as it possesses the hardness of a very high carbon steel, but less brittleness, and cups and cones made from *Duplex Cone Steel* retain their sizes and shapes when hardened.

That this brand is filling a want has been proven through its extensive use by the automobile trade during the past few years. We heartily recommend it to your attention.

SHORE SCLERESCOPE HARDNESS VALUE

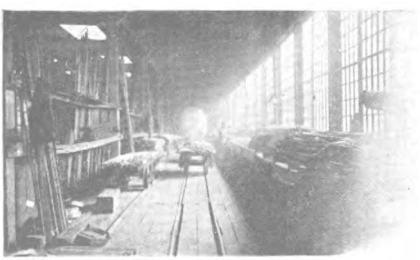
Hardened Specimen 85–100

CHROME BALL STEEL

Just as our CHROME BALL RACE STEEL is the perfection of steels for ball races, so is this brand to the ball steels. We recommend it as possessing to the highest degree those qualities required in the best ball, namely, strength, hardness and toughness.

DUPLEX BALL STEEL

This brand is second only to the foregoing brand. It makes, however, a very good high duty ball, and we believe it is the equal of any of the higher priced ball steels now on the market.

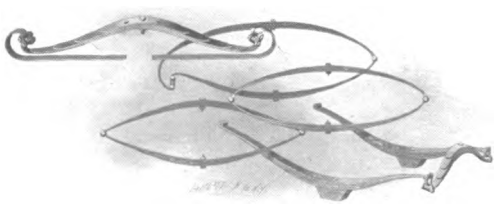


ALLOY SPRING STEELS

While investigations up to the present time indicate that the deflection under a given load is more or less the same in all steels, and in any condition of the same, yet alloy steels with their higher elastic limits, combined with greater toughness, produce springs giving the maximum of wearing service and easy riding qualities—features especially desirable in automobiles.

The alloy steel spring will endure the greatest amount of deflection without having the load exceed the elastic limit, and it is this quality that permits of a spring so designed that under service conditions it moves through a considerable distance carrying the required load with ease and an absence of that stiff and quick reaction which characterizes springs made with the less tough and necessarily stiff carbon steel.

It seems, therefore, that the best spring steel is that which readily lends itself to the various operations necessary for the production of the finished spring, and shows in its final condition the ability to withstand without breaking or yielding the greatest load coupled with the greatest amount of deflection. Having in mind these facts, we call your attention to the following brands and the table of some tests of the same given on the following pages.



ALLOY SPRING STEELS

(Continued)

DEFLECTION TESTS

Test specimens . . . . . 2.50 x .259 x 15 inches
Distance between supports . . . . . 10.25 inches

Load was applied midway between supports.

	Deflection at Elastic Limit	Load in Pounds	Fibre Stress Per Square Inch
Duplex spring steel	.953	3,120	286,000
Alva spring steel	.855	2,800	256,000
Silico-manganese spring steel . .	.860	2,820	258,000
Carbon spring steel	.733	2,400	220,000

DUPLEX SPRING STEEL

This brand is the best of the alloy spring steels, as indicated in the preceding table. In it are combined to the highest degree those qualities necessary for the production of the superior spring. The manufacturers who handle this steel, with a little care, will be well repaid for their pains by the admirable results obtained.

TENSILE TEST VALUES

Rolled Specimen		Tempered Specimen
135,000	Elastic limit, pounds per square inch . .	180,000
180,000	Ultimate strength, pounds per square inch	210,000
12%	Elongation in two inches	15%
20%	Reduction of area	40%

ALVA SPRING STEEL

This is a chrome-vanadium alloy, manufactured with the greatest care and with those considerations so necessary for the successful manufacture of this type of steel.

TENSILE TEST VALUE

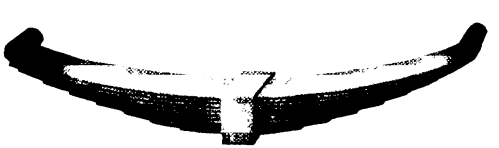
	Tempered Specimen
Elastic limit, pounds per square inch	175,000
Ultimate strength, pounds per square inch	190,000
Elongation in two inches	10%

SILICO-MANGANESE SPRING STEEL

This brand of spring steel has met with much favor both here and abroad, and if carefully handled it will produce the best spring obtainable from steel of this price, and we heartily recommend it.

TENSILE TEST VALUE

	Tempered Specimen
Elastic limit, pounds per square inch	175,000
Ultimate strength, pounds per square inch	195,000
Elongation in two inches	8%



SANDERSON SPECIAL PERMANENT MAGNET STEEL

Our Sanderson Works were the first in this country to successfully solve the difficult problem of making high grade permanent magnet steel, and to-day this product of ours excells all others in possessing the highest permanency and coercive force.

Our method of manufacture assures to our customers steel which will give the desired results, inasmuch as before shipment is made, samples of the finished bars are hardened, tested for permeability, coercive force, and residual density. Furthermore, magnets are made and run on a magneto block, when the output of the same, both before and after aging, is recorded on a meter. In fact the manufacture of our Sanderson Special Permanent Magnet Steel has been reduced to a science, with the result that it has become the standard of the country, and magnets constructed of this product deliver the current to operate the automobile, motor boat, or gas engine equipment, and in motor parlance, "Gets you there and back."

In all kinds of meters, where magnets of the highest permanency are essential, and in generators, receivers and ringers of the best telephone instruments, this high grade permanent magnet steel is used exclusively.

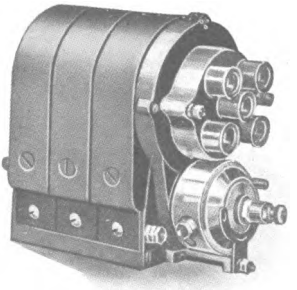
We furnish bars or sheets of this steel of sufficient softness to shear or saw with ease. Small sections can be bent to shape cold, while larger or irregular sections should be formed hot. Regarding the further properties and methods of handling this, our highest grade permanent magnet steel, it will give us pleasure to advise you, and to undertake possible improvements in your magnetic results.

ALLOY STEELS

(Concluded)

In concluding our presentation of the foremost brands of our alloy steels, we feel constrained to call attention to the fact that we are making many other special steels of various compositions, in which certain desirable properties are especially accentuated or developed to meet the needs of specific instances, viz: those high in silicon or manganese, known as *silico-manganese steels, or mangano-silicon steels*; those with larger or smaller amounts of chromium or carbon, chromium and vanadium, or possibly tungsten, or those with molybdenum and it would seem from the developments we have made towards obtaining in commercial quantities, the elements Uranium and even Radium, we may be able to present to your notice steels of these types with desirable characteristics.

The demand for these, our special alloy steels, has steadily increased, demonstrating that the public has accorded them the appreciation which their valuable characteristics fully warrant.

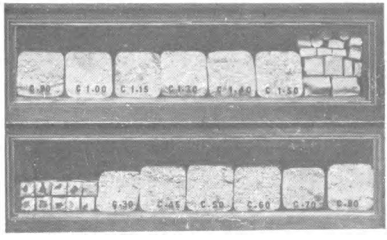


CARBON STEELS

Under this head are included those products which cannot be classed as ALLOY STEELS. They are composed principally of iron and carbon, together with the impurities that accompany these and the elements added to make the manufacturing successful.

However, just as there are race horses and nags, draught animals and horses unable to do more than stand, all horses, so are there carbon steels; some free from physical defects, clean, forgeable and responding well to treatments, others the reverse, having a tendency to crumble in forging, and contaminated with slag, oxides, etc. Some tough and strong, others weak and brittle, without life so to speak, all steels, mayhap of the same general analysis, yet so different in characteristics.

Modern science has shown that this apparently simple material called "steel," is in reality quite complex, and in order to manufacture it successfully to meet the exacting requirements of recent times, care and a thorough knowledge of the same are essential. To this end, we are employing the most skilled and experienced labor, and the best metallurgical ability obtainable, and have adopted the most improved appliances and instruments for control. It is not our intention, however, at this time, to go in detail into our methods of manufacture, inasmuch as it is well known that our mills are operated by men with years of experience, and the success met by our products in past years really tells the whole story.



Fractures

AURORA SPECIAL STEELS

To meet the most exacting requirements of the engineer, where the highest type of simple or straight carbon steels are to be used, we have developed this particular brand, which is to this class of steels what the best of tool steel is to the lowest grade. We guarantee this brand to be the most perfect possible to manufacture. It is free from physical imperfections of all kinds, and leaves our mills in its best possible physical condition. Furthermore, on account of its grade, it will stand the severest mishandling without suffering great deterioration of its potential qualities. We recommend it, therefore, for all high class forgings or machined parts. On account of its purity and consequent toughness, it however does not machine as smoothly as the more ordinary grades of steel to be described later.

Our AURORA SPECIAL is furnished in two tempers: the AURORA SPECIAL CASE-HARDENING STEEL for case-hardening purposes, and the AURORA SPECIAL FORGING STEEL for forgings and parts requiring subsequent toughening treatment only, or to be used in the forged condition.

AURORA SPECIAL STEELS

(Continued)

PHYSICAL CHARACTERISTICS

TENSILE TESTS

Aurora Special Case-hardening Steel. Forging Specimen		Aurora Special Forging Steel. Treated Specimen
38,200	Elastic limit, pounds per square inch . .	60,000
63,200	Tensile strength, pounds per square inch	85,300
26.5%	Elongation in two inches	23%
51.1%	Reduction of area	61%

BRINELL HARDNESS VALUES

Forging Specimen	Treated Specimen
163	202

TORSION TESTS

Forging Specimen	Specimen { 18 Inches Long, 1 Inch Diameter	Treated Specimen
5,500	Elastic limit, inch pounds	9,000
9,500	Tensile strength, inch pounds	20,000
220	Degrees of twist at rupture, per inch length	250

AURORA STEELS

The success that has attended this well known steel warrants us in the statement that for a high grade forging steel, one superior to the ordinary "soft forging steels," this brand excels all such now on the market, except the brand just described. For spring-hangers, spindles, gears, etc., in automobiles, chain parts, etc., it is well adapted. It is carefully manufactured, free from seams and similar defects, all of which commend it for the manufacture of intricate forgings. Like the preceding brand, AURORA is made in two tempers—the AURORA CASE-HARDENING STEEL, which is best adapted to parts to be case-hardened, and the AURORA FORGING STEEL, intended for toughened forgings.

The physical characteristics of the AURORA STEELS are much the same as those of the AURORA SPECIAL.

CARBON SPRING STEELS

CRUCIBLE SPRING STEEL

This brand is a very excellent grade of straight carbon steel, at a reasonable price, carefully manufactured, and of a quality next to the alloy products used for spring manufacture.

The tests given in the table on page 51 indicate its quality and properties.

STANDARD SPRING STEEL

As the name indicates, this is a good grade of material such as is in general use today for the manufacture of springs. It is second to none of the low priced steels on the market, and we recommend it for the manufacture of springs such as are used in many of the low priced automobiles and generally all over the country in machines or appliances where springs are essential.

SOFT STEELS

For purposes which do not require an absolutely perfect steel, but in which it is desirable to use a steel of a better quality than ordinary mill bars—we recommend our SOFT STEELS, which are given careful attention and inspection in our mill operations, to guard against physical imperfections, although we do not guarantee them to be entirely free from slight defects, which cannot be detected except by the special manipulations through which our AURORA SPECIAL and AURORA grades pass before leaving our mills. This steel is made in small, specially constructed furnaces, built with a view to high grade melting, and has inherent properties which cannot be obtained in large furnaces, where tonnage rather than quality is the object.

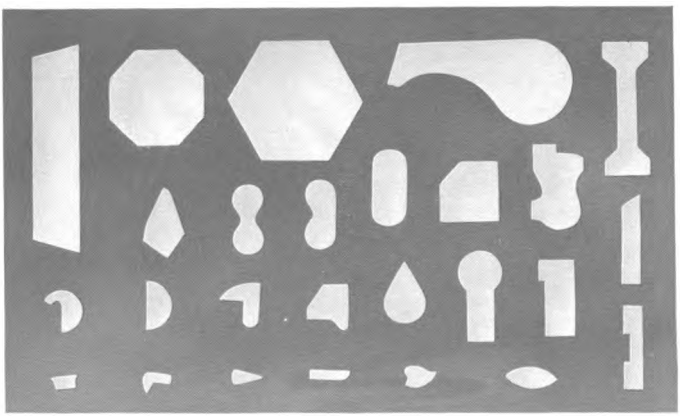
These steels are furnished in any carbon, therefore, in making inquiries please state if possible the purpose for which the steel is to be used. We would also add that these steels are manufactured *hand rolled* or *guide rolled*, the former being more perfect in shape, and more exact in size.

MACHINERY STEELS

We have manufactured for many years brands of this class of steel, and so satisfactory have they proven that their names have become standard. We need only refer to "Calumet," "Atlas," "Corona" and "Empire," which mean easy, smooth, and clean machining qualities, the qualities of prime consideration in this class of steels, which are intended for machine parts not subject to severe shocks and strains.

COLD-DRAWN AND COLD-ROLLED STEELS

We are well equipped for drawing unusual shapes for special requirements, and supplying the same of most any of the grades enumerated in the preceding pages. The advantage of using steel drawn to a particular shape is so obvious, especially where a quantity of similar parts is to be produced, it is not necessary for us to elaborate further on this subject. We have in stock a great variety of dies and rolls for producing a large number of divers shapes and will gladly take up in person any inquiries.



Some Sections of Cold-drawn Steels

SHAFT AND AXLE STEEL

Aside from our facilities for furnishing our various steels in ordinary bars in hot finished condition, we are equipped to supply almost all of the grades, both alloy and straight carbon, previously mentioned, in bars for shafts and axles possessing definite physical properties, especially accurate in size and with a Special Hot Finish, Cold Drawn or Cold Rolled, Extra Special Cold Finish surface.

SPECIAL HOT FINISH

There are many cases where it is desired to have a shaft or axle of high tensile test values, and yet machinable; in these instances we recommend our *Special Hot Finish* high tensile bars which are as free as possible from internal strains, and therefore do not warp or bow when machined. These we are in position to supply with an elastic limit as high as 120,000 pounds per square inch.

COLD DRAWN OR COLD ROLLED FINISH

Our Cold Drawn or Cold Rolled Shafts of high tensile test possess an exceptional surface or finish for this class of product, and for axles and propeller shafts in automobiles and other shafts which do not carry heavily loaded bearings this Cold Drawn or Cold Rolled Shaft Steel is especially recommended. We can furnish this stock showing an elastic limit of 140,000 pounds per square inch.

EXTRA SPECIAL COLD FINISH

Where a high tensile shaft is required, carrying a heavy load on the bearings, as for instance in the semi-floating type of an automobile axle, our Extra Special Cold Finish shaft steel, showing a very high elastic limit, will be found most efficient and it may show a value of more than 120,000 pounds per square inch, although it must be borne in mind that the facility with which these classes of materials can be machined, decreases with the increase of the tensile test values; therefore in accordance with the general idea of cold drawn or turned bars the machining should be minimized.

In addition to the superior physical qualities and accuracy of size, the many other advantages of securing material in such finished condition are obvious, and will at once appeal to the practical mind. The exceeding uniformity of our Shafts, with definite physical properties and finish, is a feature to be especially noted as it is the result of our years of study and effort, and to-day, due to our modern equipment and methods of testing, our product excels all others.

We will be glad indeed to go into further detail regarding this Axle and Shafting Steel, if you will advise us of your requirements, and in this connection please bear in mind the use of this material is not limited to Automobile construction, but is applicable to a wide range of purposes, such as machine shafts, spindles, arbors and other parts in modern high speed machine equipment.

CONVENIENT AND USEFUL FORMULÆ

FORMULA FOR THE TORQUE ON A SHAFT PER HORSE POWER

$$Pp = \frac{63030}{2\pi} \frac{H}{N}$$

P = Load in pounds applied on a lever arm at a distance "p" inches from the axis.
Pp = Twisting moment in inch pounds.
H = Horse-power.
N = Revolutions per minute.

FORMULA FOR THE DESIGN OF A STEEL SHAFT

	Turned	Cold Rolled
For simply transmitting power and short counter shafts, bearings not more than 8 ft. apart, based on the following allowable stresses:—	$H.P. = \frac{d^3R}{50}$	$H.P. = \frac{d^3R}{40}$
Turned Shafts:—	6,420 lbs.	
Cold Rolled Shafts:—	8,025 lbs.	
As second movers, or line shafts, bearings 8 ft. or less apart, based on the following allowable stresses:—	$H.P. = \frac{d^3R}{90}$	$H.P. = \frac{d^3R}{70}$
Turned Shafts:—	3,570 lbs.	
Cold Rolled Shafts:—	4,576 lbs.	
As prime movers or head shafts carrying main driving pulley or gear, well supported by bearings, based on the following allowable stresses:	$H.P. = \frac{d^3R}{125}$	$H.P. = \frac{d^3R}{100}$
Turned Shafts:—	2,570 lbs.	
Cold Rolled Shafts:—	3,210 lbs.	

H.P. = Horse-power.
R = Revolutions per minute.
d = Diameter of Shaft in inches.

NOTE:—With our shafting in the various finishes and conditions, the allowable stresses are doubled and even tripled, with a consequent reduction in the weight of the shaft or an increase in the factor of safety, whichever may be the needs of the particular case, as may be seen by reference to our strain diagrams given under the various brands of steels.

FORMULA FOR THE TORQUE ON ROUND BARS

$Pp = S. \frac{1}{16} \pi d^3$

P = Load in pounds applied on a lever arm at a distance "p" inches from the axis.

Pp = Twisting moment in inch-pounds.

S = Fibre-stress at outermost fibre in pounds.

d = Diameter of bar in inches.

FORMULA FOR TORQUE ON RECTANGULAR AND SQUARE BARS

$Pp = 0.2222\ b\ d^2\ S$

P = Load in pounds applied on a lever arm at a distance "p" inches from the axis.

Pp = Twisting moment in inch-pounds.

S = Fibre-stress in pounds at the outermost fibre.

For a rectangular bar, "b" and "d" are respectively the long and short sides of the rectangle.

For a square bar, "b" = "d", transforming the formula to:—

$Pp = 0.2222\ d^3\ S.$

FORMULA FOR THE ELASTIC RESISTANCE TO TORSION FOR A ROUND SHAFT

$$\alpha = \frac{583.6\ Pp}{d^4\ G}$$

l = Length of bar being twisted in inches.

d = Diameter of shaft in inches.

α = Angle through which the free end of the shaft is twisted, measured in degrees.

P = Load in pounds applied on a lever arm at a distance "p" inches from the axis.

Pp = Twisting moment in inch pounds.

G = Torsional modulus of elasticity. (The value of "G" is given by different authorities as from $\frac{1}{3}$ to $\frac{2}{5}$ of "E," the modulus of elasticity for tension. For steel it is generally taken as 12,000,000 lbs. per square inch.)

The angle of twist of a round shaft is about 43% greater than that of a square one.

The strength of a square shaft of side "d" is about 13% greater than that of a round shaft of diameter "d", the shearing unit stress being the same in the two cases.

FORMULA FOR A TRANSVERSE STRAIN ON A ROUND BAR, SUPPORTED AT THE ENDS, LOADED IN THE MIDDLE

$$P.\ l. = S.\tfrac{1}{6}\pi d^3$$

P = Load in pounds applied at the middle of the bar.
l = Distance between supports in inches.
S = Fibre stress in pounds at the outermost fiber.
d = Diameter of bar in inches.

FORMULA FOR THE DEFLECTION OF A ROUND BAR, SUPPORTED AT THE ENDS, LOADED IN THE MIDDLE

$$\Delta = \frac{8\,P\,l^3}{6\,E\,\pi\,d^4}$$

Δ = Deflection in inches.
P = Load in pounds applied at the middle of the bar.
l = Distance between supports in inches.
d = Diameter of bar in inches.
E = Modulus of Elasticity.

FORMULA FOR TRANSVERSE STRAIN ON A RECTANGULAR OR SQUARE BAR SUPPORTED AT THE ENDS, LOADED IN THE MIDDLE

$$Pl = 2/3\ S.\ b\ d^2$$

P = Load in pounds applied at the middle of the bar.
l = Distance between supports in inches.
S = Fibre stress in pounds at the outermost fibre.

For a rectangular bar "b" and "d" are respectively the long and short sides of the rectangle.

For a square bar "b" = "d," transforming the formula to $Pl = 2/3\ S\ d^3$

FORMULA FOR THE DEFLECTION OF A RECTANGULAR OR SQUARE BAR SUPPORTED AT THE ENDS, LOADED IN THE MIDDLE

$$\Delta = \frac{3}{12} \frac{P l^3}{E b d^3}$$

Δ = Deflection in inches.
P = Load in pounds applied at the middle of the bar.
l = Distance between supports in inches.
E = Modulus of elasticity.

For a rectangular bar "b" and "d" are respectively the long and short side of the rectangle.

For a square bar "b" = "d", transforming the formula to

$$\Delta = \frac{3}{12} \frac{P l^3}{E d^4}$$

CONCLUSION

In the foregoing pages, we have endeavored to set before you as briefly as consistent with clearness, the various products of our manufacture, their qualities and properties, and we feel sure you will see that our products are not only best adapted to your requirements—but are economic necessities.

We are the largest producers, and with our numerous branches scattered over the world, it is evident our distribution facilities are unequalled. Our travelers are everywhere, consequently in touch with the problems of each locality, all of which tends to broaden our comprehension of your individual requirements; furthermore our Research Department is always busy developing new ideas and cooperating with the users of steel and its alloys, thus through us you are sure to obtain the best assistance towards the solution of your problems which science and wide range of experience can offer.

To you, the skilled engineer and practical man, we submit the useful formulæ upon the preceding pages for your convenience, with the hope that all that this booklet contains may aid you in the solution of your problems and the attainment of greater things.